MODIS Semi-annual Report
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Abstract

Major efforts over the past six months included: (i) post-delivery work on the level 2 cloud optical depth and level 3 MODIS atmosphere algorithms; (ii) development of visualization and analysis software for use by all members of the MODIS atmosphere group; (iii) continued analysis of MAS and CAR data from various Arctic experiments; and (iv) participation in planning meetings and site surveys for the SAFARI 2000 experiment in southern Africa.

I. Task Objectives

With the use of related airborne instrumentation, such as the MODIS Airborne Simulator (MAS) and Cloud Absorption Radiometer (CAR), our primary objective is to extend and expand algorithms for retrieving the optical thickness and effective radius of clouds from radiation measurements to be obtained from the Moderate Resolution Imaging Spectroradiometer (MODIS). The secondary objective is to obtain an enhanced knowledge of surface angular and spectral properties that can be inferred from airborne directional radiance measurements.

II. Work Accomplished

a. MODIS Code Delivery and Related Software Development

MOD06 Level-2 cloud retrieval code

Mark Gray has been examining the code to determine the cause of some unusually large optical thicknesses retrieved during with the MAS FIRE-ACE data set. The problem has been traced back, in part, to reflectance library values used by the code. Software has been developed to visualize the libraries; comparison of the library values with other datasets is on-going.

New deliveries of the Level-2 processing package were made to SDST including a newly integrated and updated ancillary data package from Jason Li.

The MODIS code has to date been a single package for MODIS and MAS processing. It has now been split into separate packages that share the same science but allow for development of distinct data I/O, ancillary, and other instrument-specific routines.

MOD08 Level-3 atmosphere code

The following work was completed:

a. MOD08 File Specification Changes. Paul Hubanks completed the implementation of file spec changes for the MOD08 Daily, Eight-Day and Monthly Products as requested by the MODIS Atmosphere Group. These changes include the addition of over 150 new Scientific Data Sets (SDSs) to each product file. In addition, some changes were made to the file specifications to correct previous errors in local attribute definition.

b. Generation of new HDF Structure Files. Hubanks completed the generation of new HDF structure files for the MOD08 Tile and Daily Products. All together, 36 new tile HDF structure files where delivered to SDST and 1 new daily HDF structure file. The new structure files reflect recent changes made in the file specs. Also, the generation of new HDF structure files for the MOD08 Eight-Day and Monthly Products were completed and delivered to SDST .

c. Redelivery of new MOD_PR08T code. Eric Moody worked on refining and correcting MOD08 Level-3 software for regression statistics and QA code, which was then re-delivered to SDST.

MODIS Atmosphere web site development

Paul Hubanks has continued with the MODIS-Atmosphere web site development. The first draft of the MOD04_L2, MOD05_L2, MOD06_L2, MOD07_L2, MOD35_L2, MOD08_D3, MOD08_E3, and MOD08_M3 product sites have been complete. Over 130 web pages have been implemented thus far. The web site can be viewed at: http://modis-atmos.gsfc.nasa.gov. These product sites contain information related to format and content, grids and mapping, sample/browse imagery, QA information, news and status, data acquisition, HDF filename conventions, analysis tools, theoretical basis, file specs, production software, production plan, and support team.

Hubanks has also created a MODIS-Atmosphere Validation page, updated the Reference page, updated the MOD08_D3, MOD08_E3, and MOD08_M3 Format & Content pages to reflect the recent changes made to the product (noted above). A new SDS summary table on the MOD08_D3 product was also created.

MODIS product visualizations and other software tools

Eric Moody has developed the following code:

1. Spatial and SDS subsetting of Level-2 and Level-1B HDF granules. This subsetting code is intended to aid in data transfer to researchers outside of NASA Goddard by reducing the granule file size. Subsetted data is placed in a new

HDF file that includes all original metadata and data set attributes.

2. A graphical interface for determining which granules are associated with a data point on a Level 3 (MOD08) global map. This is intended to aid in code troubleshooting. The tool will be used by groups at NASA GSFC and the University of Wisconsin.

3. Plotting of the aerosol product MOD04 QA information. Specifically, this will produce daily plots of QA statistics from the MOD04 metadata. This will be used by the MODIS aerosol group at NASA GSFC.

Paul Hubanks has worked on MOD08 browse imagery visualizations, including:

1. Development of an automated browse creation IDL script to create a complete set of browse images that represent the entire MODIS Atmosphere Daily Global Joint (MOD08_D3) product. Ran this script on the MOD08_D3 HDF product file generated from the MODIS N-Day, J-Day, and Y-Day test data sets. Produced over 1500 images from the 400 scientific data sets contained within this file and ported them to the MODIS-Atmosphere web site for testing purposes.

2. Modified the automated browse image script to remap Lat-Lon (equal angle) projection maps to the Hammer-Atoff (equal area) projection. Added continental and political boundaries to the images. Continued work on optimizing the browse creation software, developed javascripts to display the images on the MODIS-Atmosphere web site, designed an operational directory tree structure, and developed a browse image file naming convention for production.

3. Designed and developed a web based browse system user interface for MOD08_D3 using javascript. The browse system user interface can be viewed and tested at:

   http://modis-atmos.gsfc.nasa.gov/MOD08_D3/browse.html

Mark Gray has worked on several visualization projects, as outlined below:

1. Daily Level-2 statistics generation. IDL code has been written to generate statistics on a granule by granule basis and produce an output image summary for a day of accumulated granules. The output image is suitable for inclusion in a webpage. Currently some basic statistics can be generated (an accumulation of histograms for each granule for a day sorted by time or latitude for instance). The code has been written as generally as possible so that we can change and add additional statistics as we refine our QA and validation requirements.

2. Web interface. A large amount of data will need to be examined for post

launch validation. A web interface is under development that will allow the user to view a summary image (statistic or quicklook view of a scene) and select a point for which a higher resolution image can be viewed. A web interface was chosen for this tool due to its flexibility and ease of use (similar to SeaWiFS web interface). This work has been coordinated with Hubanks to ensure compatibility with the current MODIS-Atmosphere webpage. This work is on-going.

3. Scheduling and data management. With high rates of data transfer and large numbers of files, care must be taken with managing files and resources. Dave Makofski has taken the lead on much of the scheduling work and code. Some work has been done as part of the statistics generation code to schedule processing and file handling.

b. MODIS-related Instrument Research

Cloud Absorption Radiometer (CAR) modification

Planned/current CAR modifications by Code 553 have been coordinated by Charles Gatebe. They include:

1. Upgrade/replace instrument electronics and data storage: Update digitization from 10 bits to 12 bits; build new data storage system to replace existing exabyte drive; implement new commercial LabView software control (with features such as data analysis, visualization, instrument control, etc.); improve data acquisition system; increase the SNR by digitizing the signal at the source, replace old cabling, etc.

2. Spectral modifications: Install two interference filters to correspond to the TOMS UVA channels at 340 and 380 nm. This involves modifying the optical train of the CAR with a new mechanical/optical package. These new spectral channels will allow CAR UV measurements for comparison with the TOMS aerosol index and ground-based sunphotometers.

Jason Li has also assisted Code 553 engineers on CAR hardware upgrade related issues, providing examples of previously collected data (plots, diagrams etc.) to assist them in understanding the CAR instrument. Tom Arnold conducted a CAR radiometric calibration for engineering purposes.

CAR Data processing

Jason Li completed the redesign of the CAR level-1B processing software package. The approach follows from the MODIS data processing paradigm: Level-0 to Level-1A to Level-1B. This stepwise processing strategy allows for correction of any navigation data problems. Level-2 products are on the table for discussion.

Jason Li completed CAR FIRE/ACE data processing and QA (using the new software package) and delivered the tapes to the NASA Langley DAAC, including the required 18-page submission form. He also wrote CAR Level-1B readers in IDL, FORTRAN and C language for public release. He substantially updated the CAR web pages as well.

Jason Li is in the process of re-writing the CAR BRDF processing software to include the difficult task of correcting for the CAR pitch angle in viewing geometry calculations.

Tom Arnold began the process of backing-up all CAR data previous to 1998. Backups will be to both DLT (Raw, HDF, and BRDF data) and CD-ROM (raw data) media. Backup of Kuwait and SCAR-A data has been completed.

MODIS Airborne Simulator (MAS)

Several MAS upgrades are being implemented by NASA Ames Research Center in collaboration with NASA Goddard Space Flight Center and NOAA/CIMSS at the University of Wisconsin. These include: linear variable filters on the infrared array, new blackbodies with Nextel paint, replacement of exabyte tape drives with hard disks, 16 bit data processing, replacement of old dichroics, redesign of port 4 dewar mounts and pressure release valve, and rewriting the L1B processing code.

A meeting to discuss these upgrades and other issues (e.g., calibration, data processing, etc.) was held at Goddard on October 19-20, 1999. Steve Platnick gave presentations on integrating sphere water vapor effects, and shortcomings of exoatmospheric irradiances compilations needed for MAS reflectance processing.

c. MODIS-related Field Campaign Efforts

Several members of the group (King, Tsay, Gatebe, Platnick) took part in planning meetings and site surveys for the Southern Africa Regional Science Initiative year 2000 experiment (*SAFARI 2000*). This experiment, to be conducted during several periods in southern Africa, including both wet and dry seasons, will study biomass burning, industrial pollution, land surface-atmosphere processes, cloud and precipitation processes, and their effects on the southern Africa ecosystem. An intensive observational period will be conducted during the dry season (August and September 2000) and include remote sensing observations from the Terra spacecraft and the NASA ER-2 (with airborne versions of MOPITT, MISR, and MODIS, as well as other instruments). The remote sensing retrievals will be validated against in situ meteorological, aerosol, and cloud data from the University of Washington CV-580 aircraft and two South Africa Weather Bureau Aerocommander 690A aircraft, as well as numerous instrumented ground sites.

d. MODIS-related Services

Meetings

1. Michael King and Steven Platnick visited various locations in Namibia, Zimbabwe, Botswana, and South Africa as part of the *SARARI 2000 Aircraft Coordination Site Survey*, 15-25 July 1999.

2. Steven Platnick, Si-Chee Tsay, and Charles Gatebe attended the *SAFARI 2000 Implementation Workshop*, Gaborone, Botswana, 26-30 July 1999.

3. Si-Chee Tsay and Charles Gatebe visited the Skukuza camp at Kruger National Park, South Africa, a proposed site for surface observations during the *SAFARI 2000* campaign, 1-3 August 1999.

4. Steven Platnick, Michael King, Tom Arnold, and Jason Li participated in the *MODIS Airborne Simulator Meeting*, NASA GSFC, 19-20 October 1999.

5. Michael King regularly attended weekly *MODIS Technical Team meetings*.

6. Mark Gray, Eric Moody, and Paul Hubanks attend the weekly *MODIS atmosphere data processing meeting*.

7. Michael King attended *Science Executive Committee* meetings in Chicago (8 September).

Presentations

1. King, M. D., 1999: Earth Observing System: Present capabilities and promises for the future. Presented at the *10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI (invited).

2. Ou, S. C., K. N. Liou, M. D. King, and S. C. Tsay, 1999: Remote sensing of cirrus cloud parameters based a 0.63-3.7 µm channel radiance correlation technique applied to AVHRR data. *Proc. 10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI.

3. Rolland, P., K. N. Liou, M. D. King, and S. C. Tsay, 1999: Remote sensing of cirrus optical and microphysical properties using MODIS channels. *Proc. 10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI.

4. Soulen, P. F., P. Yang, Y. X. Hu, B. A. Baum and M. D. King, 1999: Retrieving optical thickness and effective radius of ice clouds using MODIS: A sensitivity study. *Proc. 10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI.

5. Ackerman, S. A., C. C. Moeller, W. P. Menzel, J. D. Spinhirne, D. Hall, J. R. Wang, H. E. Revercomb, R. O. Knuteson, E. W. Eloranta, A. W. Nolin and M.

D. King, 1999: WINCE: A Winter Cloud Experiment. *Proc. 10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI.

6. Platnick, S., M. D. King, S. C. Tsay, G. T. Arnold, H. Gerber, P. V. Hobbs and A. Rangno, 1999: A technique for cloud retrievals over snow and ice surfaces with examples from FIRE-ACE. *Proc. 10th Conference on Atmospheric Radiation,* 28 June - 2 July 1999, Madison, WI.

7. King, M. D., 1999: NASA Earth observations: Past, present, and future. President's Invited Lecture, National Awards Ceremony of the Associated Scientific and Technical Societies of South Africa, 23 July 1999, Johannesburg, South Africa.

8. Tsay, S. C., M. D. King and J. Y. Li, 1999: Airborne spectral measurements of surface anisotropy. *Proc. 2nd International Workshop on Multiangular Measurements and Models,* 15-17 September 1999, Ispra, Italy.

9. Li, J. Y., S. Platnick, S. C. Tsay, M. D. King and G. T. Arnold, 1999: Application of the Cloud Absorption Radiometer in determining surface BRDF characteristics. *Proc. 2nd International Workshop on Multiangular Measurements and Models,* 15-17 September 1999, Ispra, Italy.

10. King, M. D., and S. Platnick, 1999: Clouds and radiation from the Earth Observing System. *Proc. CCSR Symposium & 3rd Aerosol-Cloud Sensing Workshop*, 1-3 December 1999, Kyoto, Japan.

11. Holben, B. N., O. Dubovik, A. Smirnov, T. Eck, N. Abuhassen, I. Slutsker, W. Newcomb, D. Tanré, Y. Kaufman, N. O'Neill, M. D. King and T. Nakajima, 1999: Aerosol optical properties climatology at selected globally distributed sites from AERONET. *Proc. CCSR Symposium & 3rd Aerosol-Cloud Sensing Workshop,* 1-3 December 1999, Kyoto, Japan.

Seminars

1. King, M. D., 1999: Earth Observing System: Present capabilities and promises for the future. Presented at the Directorate of Research & Development, University of Botswana, 14 July 1999, Gaborone, Botswana.

Community and other related efforts

Steven Platnick coordinated and co-taught a graduate course in radiative transfer during the fall 1999 semester given to students at the University of Maryland Baltimore County and Howard University.

III. Data/Analysis/Interpretation

a. FIRE-ACE

MAS FIRE-ACE cloud retrievals

MAS imagery obtained during FIRE-ACE has been used to develop modified cloud retrieval algorithms for clouds overlying snow and ice surfaces. The algorithms use only SWIR and MWIR bands (1.6, 2.1, and 3.7 µm) for which the surface reflectance of snow/ice is relatively small. Algorithm analysis and visualization (Steve Platnick and Jason Li) for several case study clouds was completed and results submitted in a paper to the *JGR* FIRE-ACE special issue. As an example, a MAS retrieval of the 3 June 1998 case study is shown in **Fig. 1** (using the 1.6 and 2.1 µm bands). This supercooled, midlevel stratus deck (264 K and 3.2 km cloud-top temperature and height, respectively) is located in the vicinity of the SHEBA ice station. Retrievals show great variability in both optical thickness and droplet effective radius. Both retrieved parameters are in good agreement with in situ instruments flown on the University of Washington Convair-580 (**Table 1**).

As a part of this validation work, Tom Arnold has been processing the latest University of Washington CV-580 navigation/microphysics data that are now in HDF “Vdata” format. Comparison of PVM cloud liquid water and effective radius data and FSSP measurements show more discrepancy than expected. Correspondence with the University of Washington about this issue is on-going.

MAS FIRE-ACE cloud mask processing

Tom Arnold developed code for using the University of Wisconsin cloud mask on MAS FIRE-ACE data, including decoding the cloud mask output file, and using this information to process the cloud retrieval algorithm “Decision Tree” for estimating cloud phase (ice, water, or undetermined). A product of his code is a 5-panel image with three images from MAS bands (typically 0.66, 1.62, and either 1.88 or 10.7 µm). The fourth image is the cloud mask result (color-coded by category and overlaid on a visible channel). The 5th image can be either the results of the phase determination (color-coded and overlaid on a visible channel) or the ecosystem map. Appropriate legends are provided. Data are processed by flight track (typically 1-3 pages per flight track). UNIX scripts have been developed to fully automate the entire process or just segments as needed for reprocessing. Additional output includes generation of summary mask/phase statistical files for each flight track, and then combined to summarize results for each flight. All MAS flights from FIREACE with valid port 4 data have been processed. Two sets of plots have been generated, one with 10.7 µm and phase images, and one with the 1.88 µm and ecosystem images. Analysis of these images and the corresponding statistical summary products are being used to determine the quality of the cloud mask and phase determination for MAS Arctic data. Example imagery is shown in **Fig. 2**.

b. CAR Analysis

CAR Bidirectional Reflectance (BRDF) analysis

During the last half-year, additional surface bidirectional reflectance measurements obtained with the CAR during the Smoke, Clouds and Radiation-Brazil (SCAR-B) experiment for the period 17 August-20 September 1995 were processed. Charles Gatebe has used these data to study the surface BRDF pattern in the MODIS 2.1 µm band relative to the 0.47 and 0.68 µm bands. The ratio of these bands is used in the MODIS remote sensing algorithm for aerosols over land. The BRDF analysis emphasizes results from off-nadir view angles compared with nadir views. Some results are shown in **Figs. 3a,b**. For the particular surfaces and viewing angles analyzed, results seem to suggest that the reflectances $R_{0.47}$ and $R_{0.67}$ are predictable from $R_{2.1}$ according to: $R_{0.47} = R_{2.1}/6$, which is a slight modification of Kaufman et al. (1997), and $R_{0.67} = R_{2.1}/2$, similar to Kaufman et al. (1997). These results hold for target viewed from the backscattered direction, but not from the forward direction.

CAR BRDF data from the LEADEX (April 1992) and ARMCAS (June 1995) experiments have been processed and analyzed by Tom Arnold, and submitted as a paper to the *International Journal of Remote Sensing*. Peter Soulen et al. submitted a paper on BRDFs acquired during the SCAR-A, TARFOX, and Kuwait oil fires experiments. In preparation for submission, Tom Arnold modified and reformatted all plots and figures, and reprocessed all BRDF data to ensure accuracy.

c. Namibian stratocumulus

Summary of previous investigations

The final couple of weeks of the SAFARI 2000 dry season campaign (10-23 September) will focus on Namibian marine stratocumulus clouds, as part of MODIS cloud retrieval validation activities. The validation effort will include the University of Washington Convair-580 *in situ* aircraft, as well as the MAS on the ER-2. In preparation for this activity, Steven Platnick has been reviewing the literature on this stratocumulus cloud regime. Only two *in situ* and remote sensing efforts have apparently been reported (Platnick and Twomey 1994, Watts et al. 1997), only one of these being in the peer-reviewed literature. This is in stark contrast to the relatively numerous California and Arctic Ocean stratus studies. Interestingly, results from the two Namibian stratus studies show droplet effective radii to be significantly less than these other marine stratocumulus regimes (see summary in **Fig. 4**). Though the Namibian studies clearly do not constitute a meaningful sample, the causes and implications of this observed discrepancy in droplet sizes are intriguing, and certainly warrant further study. The SAFARI validation work will provide the first opportunity for a comprehensive investigation of Namibian stratus.

IV. Anticipated Future Actions

1. Analysis of cloud retrieval algorithm results and performance from MODIS Terra data.

2. Refine Level-2 and Level-3 algorithms subject to MODIS Terra results.

3. Continue analysis of FIRE-ACE MAS data sets.

4. Continue studying the implication of measured CAR spectral BRDF data on the MODIS aerosol retrieval algorithm over land.

V. Problems/Corrective Actions

The main MODIS emphasis during the next reporting period is to improve the computational efficiency of the MOD06 cloud retrieval code to enable large scale processing of MODIS data in December. In addition, the radiative transfer look up libraries for ice and water clouds will be regenerated, and further tests of the software access of these libraries for cloud optical thickness and effective radius retrievals over various ecosystems will be conducted.

VI. Publications

a. Published

1. Ou, S. C., K. N. Liou, M. D. King and S. C. Tsay, 1999: Remote sensing of cirrus cloud parameters based on a 0.63-3.7 µm radiance correlation technique applied to AVHRR data. *Geophys. Res. Lett.*, **26**, 2437–2440.

2. Wan, Z., Y. Zhang, X. Ma, M. D. King, J. S. Myers and X. Li, 1999: Vicarious calibration of moderate-resolution imaging spectroradiometer airborne simulator thermal-infrared channels. *Appl. Opt.*, **18**, 6294–6306.

3. King, M. D., Y. J. Kaufman, D. Tanré and T. Nakajima, 1999: Remote sensing of tropospheric aerosols from space: Past, present, and future. *Bull. Amer. Meteor. Soc.*, **80**, 2229–2260.

4. King, M. D., and R. Greenstone, Eds., 1999: *1999 EOS Reference Handbook*, NASA NP-1999-08-134-GSFC, 361 pp.

5. Curry, J. A. P. V. Hobbs, M. D. King, D. A. Randall, P. Minnis, G. A. Isaac, J. O. Pinto, T. Uttal, A. Bucholtz, D. G. Cripe, H. Gerber, C. W. Fairall, T. J. Garrett, J. Hudson, J. M. Intrieri, C. Jakob, T. Jensen, P. Lawson, D. Marcotte, L. Nguyen, P. Pilewskie, A. Rangno, D. C. Rodgers, K. B. Strawbridge, F. P. J.

Valero, A. G. Williams, and D. Wylie, 2000: FIRE Arctic Clouds Experiment. *Bull. Amer. Meteor. Soc.*, **81**, 5–30.

b. Accepted

6. Soulen, P. F., M. D. King, S. C. Tsay, G. T. Arnold and J. Y. Li, 2000: Airborne spectral measurements of surface-atmosphere anisotropy during the SCAR-A, Kuwait oil fire, and TARFOX experiments. *J. Geophys. Res.*, in press.

7. Dubovik, O., A. Smirnov, B. N. Holben, M. D. King, Y. J. Kaufman, T. F. Eck and I. Slutsker, 1999: Quality assessments of aerosol optical properties retrieved from AERONET sun and sky-radiance measurements. *J. Geophys. Res.*, in press.

8. Baum, B. A., P. F. Soulen, K. I. Strabala, M. D. King, S. A. Ackerman, and W. P. Menzel, 2000: Remote sensing of cloud properties using MODIS Airborne Simulator imagery during SUCCESS. II: Cloud thermodynamic phase. *J. Geophys. Res.*, in press.

9. Platnick, S., P. A. Durkee, K. Nielson, J. P. Taylor, S. C. Tsay, M. D. King, R. J. Ferek, P. V. Hobbs and J. W. Rottman, 1999: The role of background cloud microphysics in the radiative formation of ship tracks. *J. Atmos. Sci.*, in press.

10. Durkee, P. A., R. E. Chartier, A. Brown, E. J. Trehubenko, S. D. Rogerson, C. Skupniewicz, K. E. Nielson, S. Platnick and M. D. King, 1999: Composite ship track characteristics. *J. Atmos. Sci.*, in press.

11. Rottman, J. W., S. Platnick and M. D. King, 2000: Airborne observations of stratus clouds during the southerly surge event of 10-11 June 1994. *Mon. Wea. Rev.*, in press.

12. King, M. D., and D. D. Herring, 1999: NASA's Earth Observing System: The transition from climate monitoring to climate change prediction. *Sci. Amer.*, in press.

13. Rolland, P., K. N. Liou, M. D. King, S. C. Tsay and G. M. McFarquhar, 2000: Remote sensing of optical and microphysical properties of cirrus clouds using MODIS channels: Methodology and sensitivity to assumptions. *J. Geophys. Res.*, in press.

14. Wen, G., S. C. Tsay, R. Cahalan and L. Oreopoulos, 1999: Retrieval of aerosol optical thickness over land by using implicit visible and mid-IR relations. *J. Geophys. Res.*, in press.

15. Ji, Q., and S. C. Tsay, 1999: On the dome effect of Eppley pyrgeometers and Eppley pyranometers. *Geophys. Res. Lett.*, in press.

c. Submitted

16. Platnick, S.: Vertical photon transport in cloud remote sensing problems. *J. Geophys. Res.*, submitted.

17. Platnick, S., J. Y. Li, M. D. King, H. Gerber, P. V. Hobbs: A solar reflectance method for retrieving cloud optical thickness and droplet size over snow and ice surfaces. *J. Geophys. Res.*, submitted.

18. Arnold, G. T., S. C. Tsay, M. D. King, J. Y. Li and P. F. Soulen, 1999: Airborne spectral measurements of surface anisotropy for Arctic sea ice and tundra. *Int. J. Remote Sens.*, submitted.

19. Gatebe, C. K., P. D. Tyson, H. J. Annegarn, G. Helas, A. M. Kinyua and S. Piketh, 1999: Characterization of aerosols at a remote high altitude site over equatorial Africa. *J. Geophys. Res.*, submitted.

20. Gatebe, C. K., P. D. Tyson, H. J. Annegarn, G. Helas, A. M. Kinyua and S. Piketh, 1999: Inter-Hemispheric transport of aerosols over continental Africa. *Atmos. Environ.*, submitted.

VII. References

Platnick, S., and S. Twomey, 1994: Determining the susceptibility of cloud albedo to changes in droplet concentration with the Advanced Very High Resolution Radiometer. *J. Appl. Meteor.*, **33**, 334–347.

Watts, P. D., P. N. Francis, M. D. Glew, P. Hignett, J. P. Taylor, and B. Hawden, 1997: Validation of ATSR-2 visible channel reflectances and cloud parameter retrievals using Meteorological Research Flight SATE 2 data. *Proc. SPIE EUROPTO*, **3220**, 258–269.

Cloud Retrieval Group, MODIS Atmosphere, MAS, and CAR web sites can be found at:

http://ltpwww.gsfc.nasa.gov/crg
http://modis-atmos.gsfc.nasa.gov
http://ltpwww.gsfc.nasa.gov/MAS
http://ltpwww.gsfc.nasa.gov/CAR

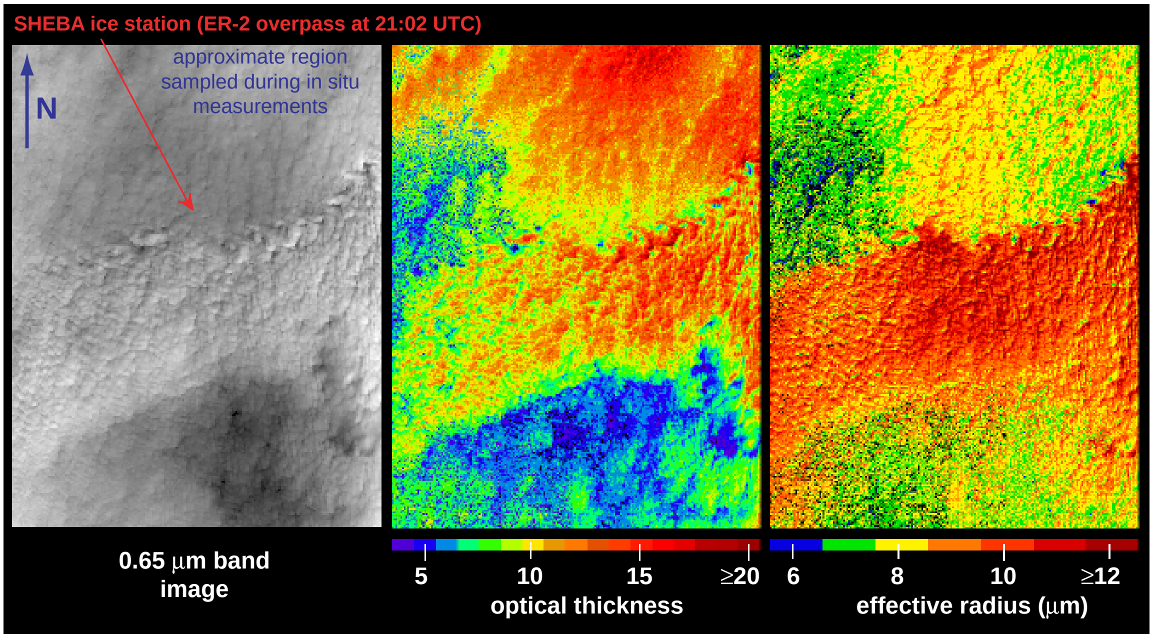

Fig. 1. MAS cloud retrievals of an extensive midlevel stratus cloud in the vicinity of the SHEBA ice station on 3 June 1998. Retrievals were made using the 1.6 and 2.1µm bands.

Table 1. MAS retrieval summary (derived from two flight tracks) and comparison with University of Washington CV-580 in situ measurements, from 3 June 1998 validation.

Parameter	MAS retrievals* (statistics)	UW CV-580 (derived from profile measurements)
τ	14.4	10.7-13.9
σ_τ	1.5	
r_e (µm)	8.3	8.1
σ_{re}	0.6	
LWP (g m^{-2})	80	45-56
σ_{LWP}	10	

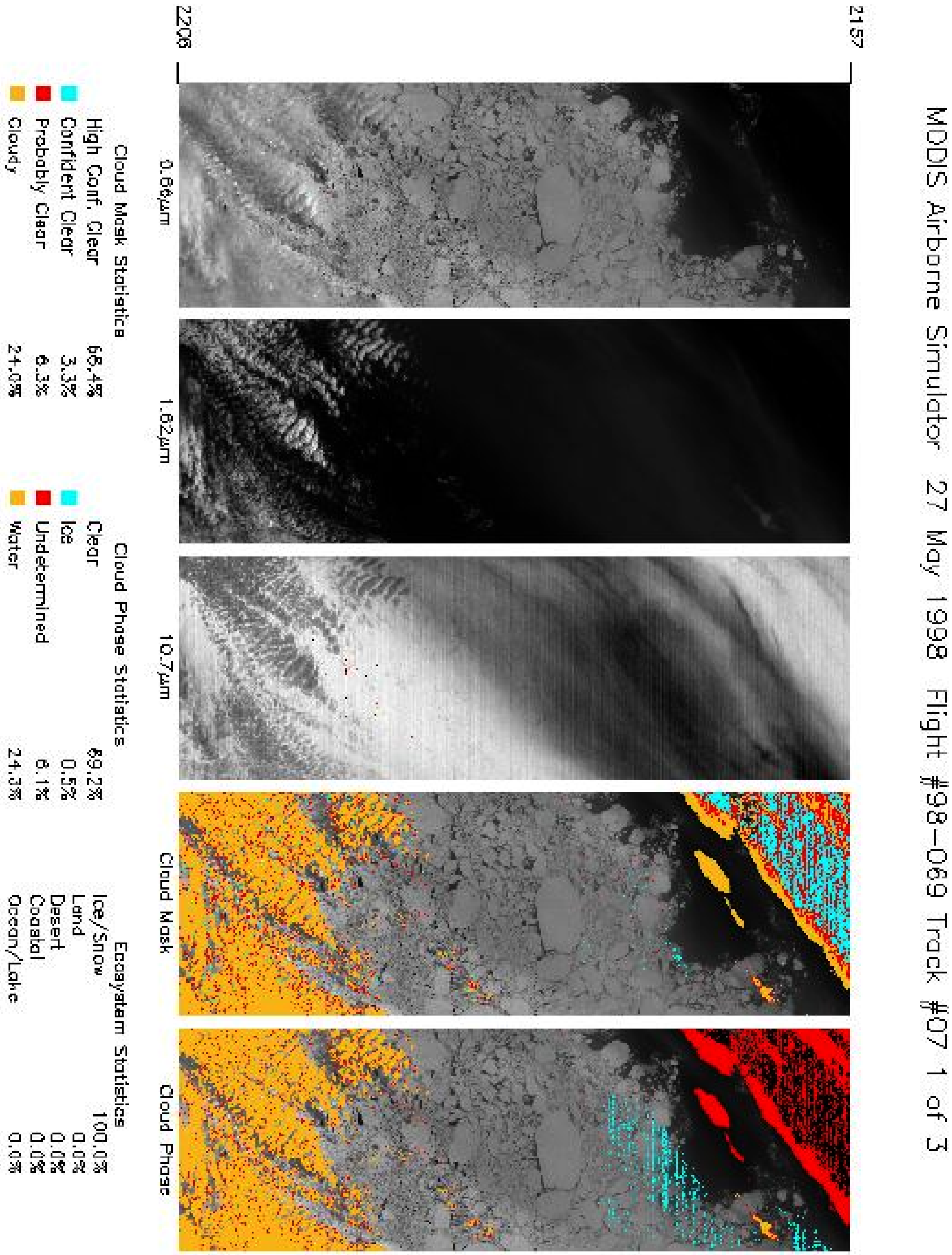

Fig. 2.. MAS spectral imagery and cloud mask over the Arctic Ocean, west-southwest of Barrow, Alaska on 27 May1998.

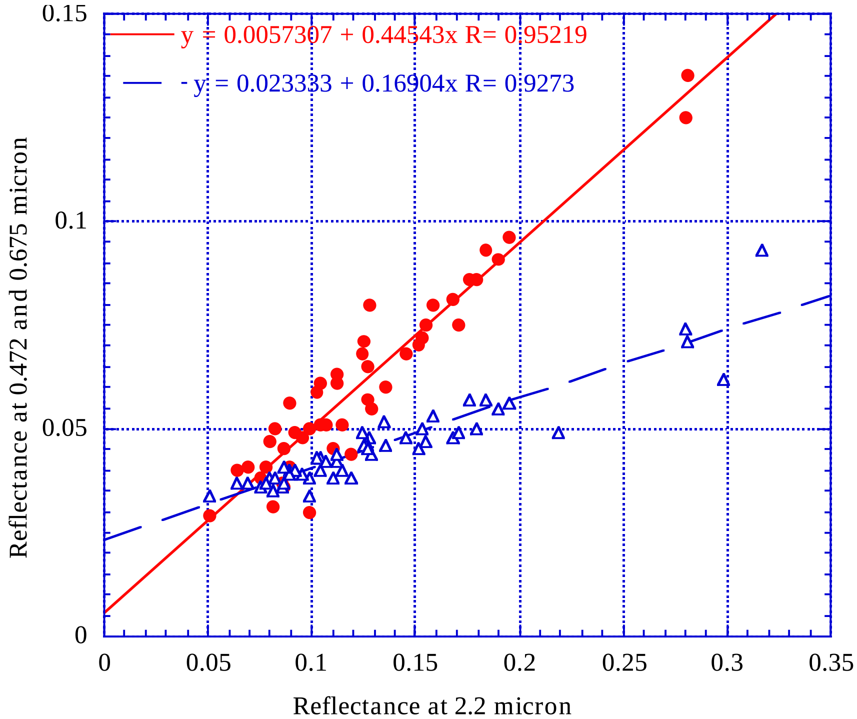

Fig 3a. Scatter plot of visible reflectance to reflectance at 2.2 µm for nadir view angle. The open blue triangular symbols represent points for 0.472 µm reflectance, while the red circular symbols represent 0.675 µm reflectance.

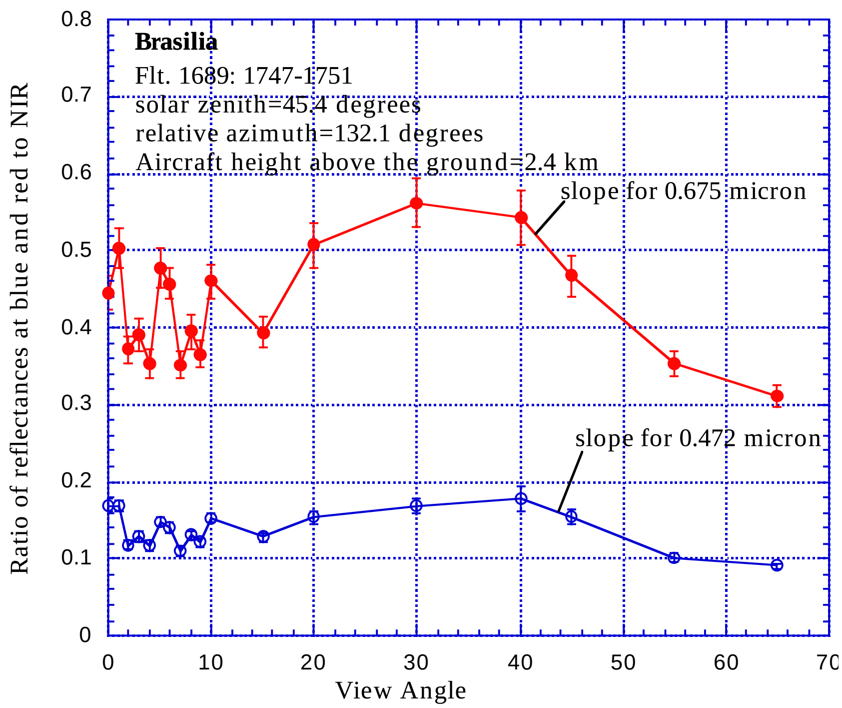

Fig. 3b. Ratio of visible reflectance to reflectance at 2.2 µm for different view angles. The open blue circular symbols represent points for reflectance at 0.472 µm, while the red circular symbols represent reflectance at 0.675 µm.

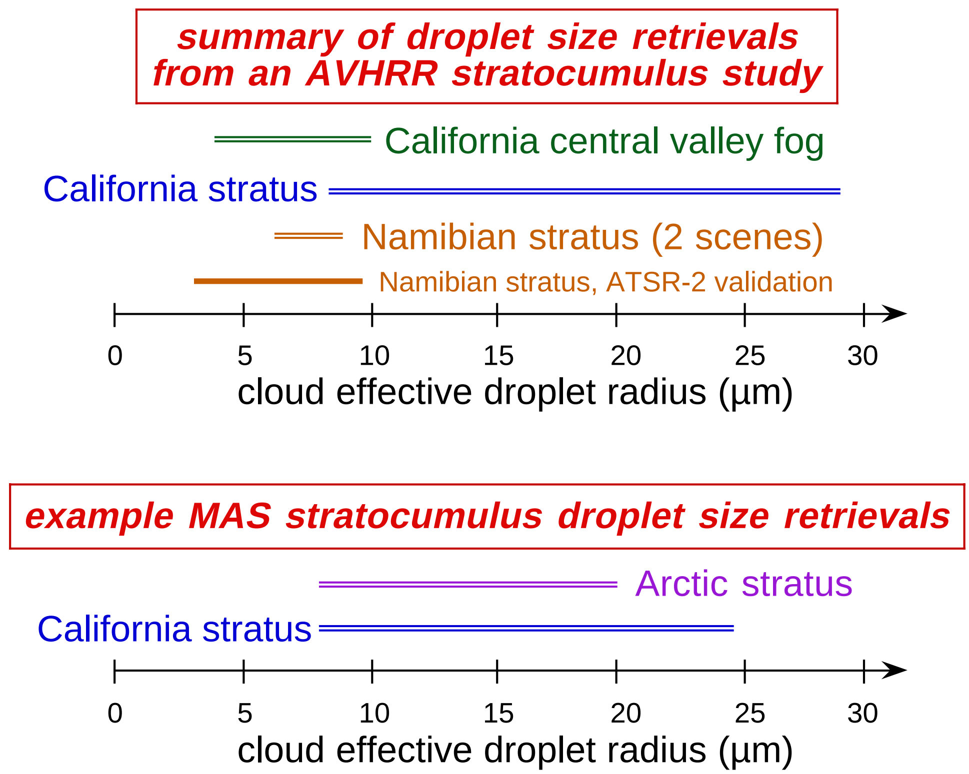

Fig. 4. Summary of various satellite (AVHRR) and airborne (MAS) droplet size retrievals from three marine stratocumulus regimes. Results from an ATSR-2 validation campaign are also shown. Though limited investigations have been made on Namibian stratus, these clouds are seen to have significantly smaller droplets than the other regimes. This intriguing result suggests further study (such as will be possible during *SAFARI 2000* dry season campaign).